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Abstract

Personality is defined as individual behavioral differences that are consistent over time and across contexts and is constructed from a number of underlying traits. Over the last 27 years, studies on pig personality have investigated links between personality traits and behavioral and physiological responses. The objective of this paper was to review the literature on personality studies in pigs. Eighty-three peer-reviewed research articles were included. The most common objective of these studies was to identify personality types in pigs by comparing their response across multiple situations. The relationship with physiological responses was the next most common objective. Results were difficult to compare as there was little consistency in terminology or experimental design across studies. Only 24.1% of the studies reported reliability and even fewer explicitly assessed validity. The backtest was the most common test (used in 67.5% of the studies), though it is unclear what specific trait is being measured. Classifying pigs as proactive or reactive personality types using the backtest was common, but the relationship between backtest results and other variables are inconsistent. The human approach, novel object, and food competition tests were also popular methods. Exploration, aggressiveness, reactivity to humans, and fearfulness were the most common personality traits studied in pig populations. There was moderate support for relationships with physiological responses. Personality was related to other behaviors, such as vocalizations and social aggression. Studies on genetic control are promising, with the heritability of personality traits falling within the range seen for other traits already selected for in pigs, suggesting these traits can be considered in breeding programs to improve welfare. Pigs with reactive personality types were more influenced by their housing environment than proactive pigs. Housing influenced reactive pigs' immune response, manipulative oral behavior, response in cognitive tasks, play behavior, and gastric lesions, which has serious implications for the management of pigs. Few studies explored the predictive power of personality traits on future physiological or behavioral outcomes of pigs, however, there is support for the potential use of personality research in improving pig welfare and productivity. In order to move forward with this field, researchers need to agree on consistent terminology and

methodologies, and investigate the reliability, validity, and practicality of common personality measures in pigs.

Keywords:

Pig, personality, coping style, temperament, behavior type

1 Introduction

1.1 Definitions and Origins of Personality

There is growing interest in using the concept of personality to study the behavior and fitness of animals, particularly as it relates to their management and welfare. The use of personality in animal management is growing in importance because it incorporates animal-based measures of how individuals are adapting to their environment and can lead to personalized care and management of animals to improve welfare, and ultimately improve physiological measures such as growth, feed intake, immune function, and meat quality (Finkemeier et al., 2018). Personality traits commonly studied in animals include boldness, exploration, sociability, aggressiveness, and activity (Réale et al., 2007; Finkemeier et al., 2018). Words often used synonymously with personality include 'coping style', 'temperament', and 'behavioral syndromes'. The term personality is frequently defined as individual differences that are consistent over time and across contexts (Sih et al., 2004; Dingemanse & Réale, 2005; Zidar et al., 2017). While temperament, behavioral syndromes, and coping style can all be defined in that same way, some researchers provide more specific definitions for each term. For example, temperament is often described as inherited, early appearing individual tendencies or an individual's response to a specific challenge (Jones & Gosling, 2005; MacKay & Haskell, 2015; Rayment et al., 2015). Behavioral syndrome refers to correlated suites of behaviors, such as in the case of more aggressive individuals who also tend to be bolder and their level of aggression in one context (i.e., interspecies interactions) can be similar to their aggression in other contexts (i.e., intraspecies interactions). Ecologists use 'behavioral syndrome' to describe population- or species-level behavioral differences and use 'behavior type' when referring to

individual differences in behavior (Sih et al., 2004; see MacKay & Haskell, 2015 for a detailed review of the definitions of temperament, personality, and behavioral syndrome). Coping style is defined as consistent differences in how individuals respond behaviorally and physiologically to stressors (Koolhaas et al., 1999; Zidar et al., 2017). For the purpose of this review, the term 'personality' will be used as a synonym for all terms above to encompass the broad concept of consistent individual differences in behavior.

Consistent individual differences are thought to be a mechanism for organisms to adapt to their environment (Sih et al., 2004; Bolhuis et al., 2005; Koolhaas, 2008). Genetic predisposition, ontogenetic development, early life environment including parental investment, social environment and nutrition have been identified as sources of individual variation that can lead to divergent personalities within a population (Dingemanse & Wolf, 2013). Behavioral variation within a population reduces competition by allowing differential niche specialization, both as it refers to resource use and social interactions (Bergmüller & Taborsky, 2010). Among gregarious species, the mix of personality types within a population can have profound effects on individual and group fitness (Sih & Watters, 2005; Hamilton & Ligocki, 2012; Sih et al., 2014). Not only does individual personality influence social structures, social environment in turn influences an animal's personality, a concept known as 'social niche specialization.' Similar to the ecological concept of niche differentiation, individuals within a social environment adjust their behavior in response to group dynamics (Bergmüller & Taborsky, 2010). Recent evidence shows that animal personality interacts with the social and physical environment to affect fitness (i.e., reproduction, mortality, disease susceptibility, predator avoidance, dispersal success). Thus, personality has powerful effects on ecological outcomes at the population, species, and community levels (Biro & Stamps, 2008; Wolf & Weissing, 2012; Belgrad et al., 2017). Animal personality traits have also been linked to underlying physiological differences among individuals. For example, personality has been associated with variation in immune response, disease and injury susceptibility, growth rate, meat quality, reproduction and maternal traits (Koolhaas & Van Reenen, 2016; Finkemeier et al., 2018). This has major implications for livestock.

There is potential for understanding of personality to be used to improve productivity and welfare within the pig industry, particularly when addressing major welfare concerns regarding aggression in group-housed pigs and destructive behaviors such as tail biting, as well as improving overall growth, health, and meat quality parameters. Over the last 27 years, many studies have been conducted to identify personality types in pigs and relate personality traits to behavioral or physiological traits important to the pig industry. However, there is a lack of consistency among the results of these studies, meaning that the implications for improvements to the management and welfare of pigs have yet to be understood or turned into management recommendations that could be applied in practice. This review seeks to identify where evidence is adequate for personality research to guide management and to highlight how personality research effort could be refined to facilitate future development of management recommendations.

1.2 Measuring Animal Personality

The most commonly accepted traits used to describe animal personalities are boldness, exploration, sociability, aggressiveness, and activity (Réale et al., 2007; Watters & Powell, 2011; Finkemeier et al., 2018). A generally accepted validation of personality traits is consistency over time and across contexts (McAdams, 1992; Réale et al., 2007; Watters & Powell, 2011). However, consistency does not imply rigidity as individuals may still have a range of reactions to certain situations that may change based on age or context. Therefore, the average of the reactions and differences among individuals should be considered as the consistency in the measure of a trait (McAdams, 1992; Réale et al., 2007; Finkemeier et al., 2018).

Fear and anxiety are assumed to be primitive emotions in animals, related to predator avoidance, and measures of animal personality appear to be strongest when animals are subjected to a stressful situation (Forkman et al., 2007; Réale et al., 2007). With livestock species, researchers are interested in measuring fear and anxiety because the animals within our care are often subjected to novel items or procedures. Livestock species are also often in the presence of and restrained by humans who may be viewed as predators by these animals, despite the fact that they may express reduced fear as a result of

domestication (Forkman et al., 2007). Chronic stress caused by ongoing exposure to fearful situations can disrupt growth rate, feeding behavior, reproductive success, and immune function; therefore, it is in the best interest of producers to reduce the amount of fear present within the environment, and to know more about what situations cause fear (Forkman et al., 2007).

Using behavior tests to measure personality traits, such as fear and anxiety, is the most common method of assessing personality in captive animals (Gosling, 2001; Watters & Powell, 2011). Behavior tests such as the novel object test and novel environment tests (i.e., open field test, emergence test, elevated plus maze test; descriptions of commonly used behavior tests are provided in Table 2) were originally designed to measure curiosity in rats (novel object test; Berlyn, 1950) and emotionality in rats and mice (Archer, 1973). More recently novel environment and object tests have been used to measure boldness, exploration, and fearfulness in a variety of species (Huang et al., 2018). As with any methodologies used to measure personality traits in animals, careful consideration of the experimental design is needed to ensure the methodology will capture the behavioral nuances of the particular species being studied (Watters & Powell, 2011). Variation across species, sex, and genetic lines are important considerations when assessing responses to behavior tests, as seen in differences in defecation rates in rats and mice in response to a novel environment test (Archer, 1973). For these reasons, it is important to consider the ecology and biology of the species being studied and from this perspective focus on the traits where the natural history would encourage greatest between-individual differences in expression (Gosling & John, 1999; Finkemeier et al., 2018). Five ecologically-relevant categories of personality traits have been suggested for personality traits in animals, along with recommendations for how these traits should be measured: 1) shyness-boldness (measured in a risky but familiar situation), 2) exploration (measured in a novel situation), 3) activity (measured in a familiar situation), 4) aggressiveness (towards conspecifics), and 5) sociability (amount of social interaction shown by an animal; Gosling, 2001; Réale et al., 2007). However, when analyzing personality traits or dimensions in a new context or in a new species, traits from a variety of categories should be measured in order to fully understand the population and to approach the idea of personality dimensions in an exploratory way (Gosling & John, 1999; Watters &

157 Powell, 2011; Huang et al., 2018). Unfortunately, proper validation of methodologies presents numerous
158 challenges for animal personality researchers who are often restricted with respect to time, resources,
159 animal populations, and trained personnel. Validation will be further discussed in section 3.1.3.
160
161 *1.3 Literature Review Objective*
162 With this literature review, our objective was to evaluate the studies of personality in pigs with a
163 goal to use this information to guide management practices and to direct future research to address
164 knowledge gaps. To achieve this goal, we summarized the methods used in the literature and highlighted
165 the themes and trends present, while also addressing the issues and inconsistencies currently present in the
166 literature and in applying findings in practice.
167
168 **2 Literature Review Methods**
169 A literature review was conducted from the Web of Science database using the scientific (*Sus*
170 *scrofa*) and common names for pigs (pig, swine, sow, boar, gilt, and barrow), along with the terms
171 'personality', 'temperament', 'behavioral type', 'behavioral syndrome', and 'coping style.' Searches were
172 conducted as "pig personality," "pig temperament," "pig behavioral type," "pig behavioral syndrome,"
173 "pig coping style," "swine personality," "swine temperament," etc. (using all terms listed for the animal
174 name and personality synonym and with both British and North American English spelling conventions).
175 The Web of Science database searches these terms equivalently to "pig AND personality," etc. The time
176 span for the search included studies published between 1864-2018 and no language exclusions were
177 applied. Empirical studies from peer-reviewed journals were retained for further review if the abstract
178 indicated the study was relevant to our objective. We did not include terms for specific personality traits
179 (e.g. aggressiveness or fearfulness) in the search, as our objective was a focus on studies investigating
180 overall personality constructs or methods of assessing personality. Additional articles were found using
181 references cited in the literature collected during the initial search. Conference proceedings and abstracts
182 are not included in this review because they lack methodological details, which were of interest in this

review. Articles were reviewed to collect information on purpose of study, personality term used, animal information (sample size, age, sex, breed), methods used for assessing personality, results of study, as well as any results assessing reliability or validity of the methods used.

3 Results

3.1 Review of the studies of personality in pigs

3.1.1. Literature Search Results

The systematic search yielded 83 articles relevant to the objective of this review, which are listed in Table 1 with the source citation, study objective, personality-related term used, sample size, breed and age of the pigs studied, and methods used. The years of publication for these articles ranged from 1991-2018. Figure 1 depicts the frequency of pig personality papers published in each year in that range.

'Coping style' and 'temperament' were the most commonly used personality synonyms, with 67.5% of the articles using 'coping style', 20.5% using 'temperament', and only 8.4% using 'personality', 1.2% using 'behavior type', and 2.4% using more than one term.

3.1.2 Animal Information

Sample sizes studied in the articles ranged from 12 to 10,033 pigs, with a median sample size of 94 pigs. A variety of purebred breeds, breed crosses, and species were used in the studies, including Duroc, Landrace, Yorkshire, Hampshire, Chester White, commercial crossbreds, Pitman-Moore minipigs, Vietnamese minipigs, Yucatan minipigs, Göettingen minipigs, wild boar, White-lipped peccary (*Tayassu pecari*), and Collared peccary (*Pecari tajacu*). Pigs studied ranged in age from 0 days to 8 years old. The majority of studies (73.5%) concluded by the time the pigs were 6 months of age, 14.5% of the studies concluded when the pigs were between 7 and 10 months of age, and 12% observed pigs over 1 year of age. Over two-thirds (63.9%) of the studies observed both sexes while 31.3% observed only female pigs, and 4.8% looked solely at males.

209 *3.1.3 Personality Assessment Methods*

210 Within the pig literature, there are several issues in finding patterns across studies. In many
211 studies, there were unclear hypotheses regarding which personality traits were being measured by the
212 reported behavior tests. There was also inconsistent application of behavior tests used to measure
213 personality traits and the statistical methods used to analyze the data. Finally, there was a lack of testing
214 or reporting on the reliability and validity of the personality assessment methods used. In order to move
215 forward with the use of animal personality in the management and welfare of pigs, these issues need to be
216 addressed in future studies.

217 The 83 studies examined used a variety of personality assessment tests. The most popular test was
218 the backtest, which was used in 67.5% of the studies. In most of the studies (67.5%), more than one test
219 was used to assess personality types. In all but two of the studies, the authors stated which personality
220 traits or dimensions they were attempting to measure with the tests they used. Some authors explicitly
221 stated a particular trait such as "fearfulness" or "aggressiveness" (54.2%). Others stated they were
222 measuring general "coping style" (57.8%), "behavioral differences/strategies" (6%), "temperament"
223 (2.4%), or "personality" (1.2%) instead of naming a specific trait. Table 2 provides a list of the behavior
224 tests used to assess personality along with lists of the traits being measured, according to the study
225 authors. Researchers often used different names for what appeared to be similar tests based on the study
226 methods; therefore Table 2 also provides a description of each test to enable comparison of results across
227 studies that may have used different terminologies originally.

228 In addition to the wide range of tests used, the diverse way in which specific tests were applied
229 makes comparisons across studies difficult. For example, with novel object tests, some researchers such
230 as van Erp-van der Kooij et al. (2002) and Reimert et al. (2013) conducted tests in the animals' home pen
231 while others such as Hayne and Gonyou (2003) and Friel et al. (2016) brought pigs to a novel test area.
232 Even further, if pigs were brought to a test arena, there was no consistency with respect to whether pigs
233 were habituated to the arena or the amount of time they were given to habituate prior to starting the tests.
234 For example, Asher et al. (2016) gave pigs a 5 min habituation period the day prior to the first novel

object test, Hayne & Gonyou (2003) gave the pigs 2 min immediately prior to the test, while Ruis et al. (2002) did not provide a habituation period. Some novel object tests were also conducted in succession with other tests. For example, the researchers would bring a pig into a novel arena for an open field test, and then introduce a human for a human approach test, and then the human would leave a novel object as they left (Hayne & Gonyou, 2003) while other researchers conducted these tests separately (for example: Forkman et al., 1995; Brown et al., 2009; Friel et al., 2016). There was also variation in whether novel object tests were conducted on isolated animals as seen in de Sevilla et al., 2009 and Friel et al., 2016 or on an animal as part of a group as seen in Brown et al., 2009 and Reimert et al., 2013. Conducting tests under multiple conditions is a way to test pigs' responses across situations and therefore is useful in understanding personality. However, a problem arises when a test conducted under different conditions is treated as always measuring exactly the same personality trait when it may be equally likely that different traits are being measured. Further validation of behavior tests would help elucidate how different test conditions, including conducting multiple tests in succession or the social context, affect pigs' responses and help us further elucidate which specific traits are being measured. Additionally, tests were conducted at different ages, and sometimes repeated multiple times on the same population with variable intervals between sessions. When tests were repeated, some researchers considered data from the repeated tests as separate measures often without reference to the risk of carry-over effects from one session to the next, while some averaged the data to make a single measure.

The backtest will be discussed as another specific example of the variations that can occur in methodologies used to assess personality within a single and widely used test. The backtest was adapted from the tonic immobility test in chickens and is frequently used as a measure of coping style, where pigs are classified as proactive (high-resisting pigs) or reactive (low-resisting pigs) (Hessing et al., 1993; Zebunke et al., 2015). It remains unclear what specific personality trait the backtest is measuring in pigs. Most researchers simply said they were used the backtest to measure 'coping style,' while two researchers specified 'fear' as the trait being measured (Erhard & Mendl, 1999; Erhard et al., 1999). The backtest was the most consistently implemented test across studies due to its simplicity but even so, there were still

inconsistencies in how the test was performed. The procedures used by Hessing et al. (1993) were often referenced but few details were provided leading to following researchers to interpret the procedures differently. Pigs were always tested individually outside of their home pen and held on their backs typically for 1 minute (though two studies conducted the backtest for a 5-minute duration; Erhard & Mendl, 1999; Erhard et al., 1999). Few studies specified how the pigs were placed on their backs-and when specifics were provided, there was variability such as pigs being placed in a V-cradle (de Sevilla et al., 2009), held on a feedbag on a table (Melotti et al., 2011) or placed on the floor (Forkman et al., 1995). Most studies recorded some combination of the frequency, duration, and/or latency of resistance or struggle attempts (Zebunke et al., 2017). There were also differences in whether the test was conducted repeatedly on the same pig and if so, the number of times each pig was tested varied, as did the length of time between repeated tests. In studies by Bolhuis et al. (2000, 2003, 2004, 2005a, 2005b, 2006), the test was conducted at 10 and 17 days of age. Hessing et al. (1993) conducted the study 5 times over the first 3 wk of age. Zebunke et al. (2015) conducted the backtest at 5, 12, 19, and 26 days of age and Archer et al. (2003) only at 7 wk of age.

Recent studies by Zebunke and colleagues (2015; 2017) aimed to validate the use of the backtest by comparing intra- and inter-test consistency and assessing the influence of classification method on the results. The backtest was conducted 4 times on the same pigs and latency, duration, and frequency of struggling were recorded. Response were compared across the 4 tests and showed moderate repeatability. There was not clear evidence for two distinct coping strategies but rather that the pigs fell on a continuum between proactive and reactive (Zebunke et al., 2015). The relationship of the backtest variables with variables recorded at mixing, in human approach, novel object, and open door tests were compared. There was low to moderate inter-test consistency suggesting that the backtest was capturing some aspect of personality, but not distinct personality types (Zebunke et al., 2017). A combination of test repetitions and variables were used to compare 4 types of classification methods to classify animals into proactive and reactive based on their distribution. Additionally, the differences in classification between correlation analysis and category analysis were assessed. The classification methods used impacted the results, with

some classification methods causing low numbers of animals to be classified as either proactive or reactive. The best method for classifying animals used the latency and duration of struggling across all 4 observations (Zebunke et al., 2017). However, despite these efforts to validate the backtest using inter- and intra-test consistency, researchers still do not have a clear understanding about what trait is being measured by the test. The inconsistent and ambiguous results seen across studies may be due to variation in methodology across studies or because the backtest is an inappropriate method for measuring personality traits in pigs.

Besides the diverse methodologies employed in administering behavior tests to measure personality traits, another issue seen within the pig personality literature was with the statistical methods used to analyze the data. Statistical analyses used for personality assessment varied widely across studies. When comparing behavioral responses across multiple situations in order to identify personality types (discussed in section 3.4.1) correlation (47.8%) and principle components/factor analysis (34.7%) were frequently implemented. The use of principle components or factor analysis in studies on animal personality has been criticized for their incorrect application due to the mistakes outlined by Budaev (2010), such as failing to specify the use of a correlation or covariance matrix, failure to test or report tests and results of sampling adequacy and providing explanations for factor rotation and number of factors retained. Researchers using principal component and factor analyses need to assess the sampling adequacy of their matrices and provide detailed information about how they conducted these analyses to allow them to be critically evaluated and reproduced.

Another issue in the pig personality literature was failure to report reliability for the tests used. Reliability is how consistent a measure is at capturing the desired variable or alternatively can be described as the level of error in the measurement (Martin & Bateson, 2007; Bartlett & Frost, 2008). Failure to report test reliability is not unique to pig personality research but is a consistent problem in personality studies of other species as well (Gosling, 2001). In applied animal behavior studies, interobserver reliability and repeatability are commonly used measures of reliability (Dalmau et al., 2017). Reliability was reported in 24.1% of the pig personality studies examined in the present literature

313 review, with repeatability as the most common measure used. Repeatability refers to the consistency in
314 the measure compared to the same measure taken in identical situations within the same subject (Bartlett
315 & Frost, 2008). Repeatability is a measure of reliability and can be informative about the robustness of a
316 behavior test. Given that across-time consistency is typically regarded as a necessary component of
317 personality, this low use of repeatability analysis is surprising. However, there are issues in the use of
318 repeatability in that animals, especially pigs, readily habituate to repeated tests causing low to moderate
319 repeatability among measures taken across tests (Dalmau et al., 2017). Because an animal's response to
320 tests can change with repeated exposures, using repeatability as a measure of reliability has been
321 questioned, and it has been suggested that the first exposure is the most appropriate measure of a
322 personality trait (Forkman et al., 2007). Repeatability values for the different tests are reported in Table 3.
323 Repeatability values for personality tests had correlation coefficients ranging from 0.11-0.92. The human
324 approach test had the lowest repeatability, suggesting that pigs may habituate quickly to the presence of
325 humans or that their response may depend on the human used in the test. The novel object test, which is
326 widely used across the personality literature, also had relatively low repeatability, which may suggest pigs
327 also habituate quickly to novelty. Alternatively, pigs' response in this test might be dependent on other
328 conditions, such as the object used, whether the pig was tested alone or in a novel arena. The food
329 competition and food motivation tests had the highest repeatability. This suggests that the pigs' response
330 to competing for food with conspecifics is relatively consistent. A meta-analysis on repeatability of
331 behavior (activity, affiliation, aggression, antipredator, courtship, exploration, foraging, habitat selection,
332 mate preference, mating, migration, parental, and other) across species of different taxa revealed the
333 average repeatability is 37% (Bell et al., 2009). This analysis did not include data on domesticated
334 animals, but many of the repeatability values presented in studies of pig personality fall around this
335 average, suggesting these tests are capturing important information on pig personality. It might be
336 expected that behavior in a controlled setting, such as on a farm or in a laboratory, would be more
337 repeatable than behavior measured in the wild, but repeatability in the field has been found to be higher
338 than in a laboratory (Bell et al., 2009). Time interval between studies also affected repeatability estimates,

with repeatability decreasing as time between measures increased. Differences in repeatability depending on the age and sex of the animals have also been documented (Bell et al., 2009). These factors should be taken into account when assessing the repeatability of personality traits in pigs and should be used to guide future studies on reliability of personality assessment methods. Reproducibility, the consistency of a measure under changing conditions (Bartlett & Frost, 2008), is a measure of reliability that is often missing from the animal personality literature and appears to be a major issue.

Finally, few studies have attempted to validate the methodologies used in animal personality research. Validity addresses whether the measurements taken allow truly representative answers to the scientific question being asked (Martin & Bateson, 2007). Validity in behavior tests for animals can be measured by comparing results across tests that are meant to measure a single trait, by comparing an animal's behavioral response in a test to their physiological or neurobiological response (Blaszczyk, 2017), and by using psychotropic drugs to compare pigs' response without and without pharmacological intervention (Donald et al., 2011). To validate the use of the open field test in pigs to measure fear, pigs were tested in with multiple interventions including treating pigs with a stress-reducing drug, providing the pig a familiar conspecific during the test, and observing how pigs' response changed with repeat exposures to the test (Donald et al., 2011). Many of the tests and traits used in animal personality studies have been adapted for use across species (Huang et al., 2018). For example, behavior while being run through a weigh scale has been used as a general measure of temperament for pigs (D'Eath et al., 2009), similar to how chute exit speed is used to assess temperament in cattle without further validation of the ecological relevance of this test in pigs. Only five studies in this review explicitly stated an aim to validate personality trait measures, and all of them used the backtest. Responses in the backtest were compared to aggressive behaviors towards conspecifics (Geverink et al., 2002; Zebunke et al., 2017) and physiological measures (Spake et al., 2012; Krause et al., 2017). Comparing behavioral responses across multiple test types is a method of testing validity; however, when multiple tests have been used to assess personality in pigs, it is unclear whether researchers were attempting to measure the same trait across multiple contexts (fearfulness in a novel object test vs. fearfulness in a human approach test; Janczak et

al., 2003a), or if they assumed different tests were measuring distinct personality traits (exploration/fearfulness in a novel object test vs. reactivity to humans in a human approach test; Brajon et al., 2016). Results often showed weak correlations between different behavior tests suggesting each test could be measuring distinct personality traits or that the tests were failing to capture personality traits at all (Huang et al., 2018). It is likely these tests are capturing distinct personality traits, but it is not always clear what specific trait. In order to properly capture personality traits in a species, it is recommended to apply multiple tests and measures in a variety of contexts to identify the prominent personality traits in that species (Huang et al., 2018). Studies on pigs have used this approach (see section 3.4.1), but due to the vast differences in methodologies applied and a focus on identifying dichotomous coping styles, pig personality research is still a long way from identifying valid personality traits and tests. Future validation studies should move away from the proactive-reactive coping styles perspective, use a variety of tests in different contexts, and utilize pharmacological interventions to validate tests for personality traits in pigs, similar to Donald and colleagues (2011). Frameworks for ecologically valid tests and traits have been proposed for use in animal personality research, suggesting five categories: shyness-boldness (or reactivity, emotionality, or fearfulness; Gosling, 2001) measured by animals' responses in a risky, but familiar situation; exploration, where an animal's response to a novel situation or towards a novel object is evaluated; activity levels monitored in a familiar situation; aggressiveness towards conspecifics; and sociability, measured by the level of social interaction an animal displays (Gosling, 2001; Réale et al., 2007). Future studies on pig personality could adopt this framework to provide consistency in this area of research, or alternatively, experts on pig behavior could create a framework specific for pigs. This would allow for comparisons across studies and the ability to synthesize the information for application to the management and welfare of pigs.

3.4 Themes and Trends in the Pig Personality Literature

The stated objectives for the reviewed studies have been consolidated into eight categories. Some studies had more than one objective, and therefore were included in the total count for each relevant

category. The categories included: comparing behavioral responses across situations to identify personality types of pigs (n=23), investigating relationships between personality and physiological parameters (n=20), examining how personality influences the prevalence of other behaviors (i.e., tail biting, maternal behavior, vocalizations, impulsivity, social aggression; n=17), exploring the heritability or genetic determination of personality (n=16), studying the effects of early-life or current housing environment on personality (n=8), testing the consistency of behavior tests in identifying personality (n=7), considering the role of personality on learning and cognition (n=5), and predicting future behavioral or physiological outcomes of the pigs based on their personality (n=5).

3.4.1 Comparing behavioral responses across situations to identify personality types

Comparison of the behavioral responses of pigs across different situations to identify personality types was the most commonly studied topic in pig personality research. The multiple contexts studied included using behavior tests designed to provide a stressor or challenge to the pigs or by observing behavior in typical commercial situations, such as in the home pen, at feeding time, or aggression after being placed into a new social group. Table 2 provides a list of the behavior tests used to assess behavior types in pigs. Figure 3 depicts pairwise comparisons between the behavior tests used by researchers under this objective. Classifications of relationships using slight, low, moderate, and high were determined as outlined in Martin & Bateson (2007). Relationships between test were 'consistent' if all the studies comparing the tests reported a relationship. Relationships between tests were 'mixed' if some researchers reported a relationship and others did not. The backtest, human approach test, novel object test, and food competition test were the most frequently used. The backtest had consistent but low relationships with the emergence, food competition, and open field/novel object tests and a moderate relationship with the social competition test. The human approach test had consistent but low relationships with the open door and resident-intruder tests, and moderate relationships with the handling-other and emergence tests. The food competition test only had low relationships with aggression at mixing and the food motivation test.

The backtest was used in 60.8% of the studies included in this category. In many of these studies, researchers were interested in investigating the theory that there are two personality types of pigs (i.e., two distinct coping styles), where pigs fall into proactive and reactive types. The response during a backtest was used to categorize the pigs as proactive, reactive, or intermediate (Zebunke et al., 2017). The pigs' responses in other situations were observed and compared to these classifications. Under the proactive versus reactive pig type hypothesis, proactive animals tend to be more aggressive, bold, and rigid in their behavioral responses. In contrast, reactive animals tend to be more shy, passive, and flexible (Koolhaas et al., 1999). The evidence for coping styles in pigs is mixed. Half of the studies investigating whether there were two distinct categories of coping styles found evidence in support of this theory and the other half did not. The inconsistent results seen from studies using the backtest are likely caused by some of the issues previously mentioned in this review, such as unclear hypotheses regarding what trait this test was measuring, inconsistent methodologies when performing the test, and different approaches used for describing the distribution of backtest responses in the population and for statistical analysis. However, the primary issue with reliance on the backtest for measuring personality in pigs is the lack of understanding on what personality trait this test measures and the inconsistent results likely indicate that is it not an ecologically relevant test for pigs.

Nearly half of the studies (47.8%) comparing behavioral responses across situations looked at inter-test correlations between test variables. In general, most significant correlations between test variables were low to moderate. A number of studies (30.4%) went beyond the coping style theory to explore the number of personality dimensions in pigs by measuring the pigs' responses to multiple tests, then using principal components or factor analysis to find the number of components or factors within the study population. As described in section 3.1.3, a framework of 5 key traits, or dimensions, have been attributed to animal personality including fearfulness, activity, aggressiveness, sociability, and exploration (Gosling, 2001; Réale et al., 2007). Most of the studies using principle component or factor analysis found 3 dimensions in the data, but the number of dimensions found ranged from 2 to 5. Exploration and aggressiveness were frequently identified as independent dimensions. Reactivity to humans was also

identified as a dimension in multiple studies. This trait is not included in the framework typically used to study animal personality from an evolutionary ecology perspective but that would be important to consider for a personality framework specific to domestic animals because domestication has generally reduced animals' fear towards humans (Forkman et al., 2007) and human-animal interactions are prevalent in animal industries (Hemsworth, 2003). According to this framework, fearfulness is measured by observing an animal's response to a risky but familiar situation (Réale et al., 2007). In many of the tests, such as human approach, novel object, and open field, the researcher specified fearfulness as the trait being measured but these tests were conducted in a novel arena, which would limit the researchers' ability to identify that fearfulness independently of exploration. The match between hypothesized personality dimensions in existing frameworks and the suitability of tests to detect and differentiate between personality dimensions should be considered and addressed in future studies. Sociability was also not a trait typically measured in the pig literature as many of the interactions with conspecifics targeted aggressive responses rather than investigating affiliative social interactions (Camerlink & Turner, 2013). Sociability was identified as a dimension in one study by the use of a social dependence test (Forkman et al., 1995). There are consistent personality dimensions present in pig populations but in order to move forward in identifying pig personality dimensions, a framework specific to pigs needs to be developed with clear criteria for how to measure each one. The framework of 5 dimensions suggested by Gosling (2001) and Réale and colleagues (2007) is a good starting point for future studies on pigs.

Surprisingly, the novel object test had few significant relationships with other tests despite its heavy use in pig personality research. The novel object test had weak relationships with the handling-movement test and food motivation test. The latency to contact a novel object was a reliable method of assessing fearfulness in pigs by Dalmau and colleagues (2017) as indicated by across-time repeatability, but the tests were done in a group in the pigs' home pen. The location of the home pen in the building had an effect on the pigs' response, with pigs housed towards the back of the room having a longer latency to approach the object than pigs housed at the front of the room with more frequent exposure to human presence and novel stimuli (Dalmau et al., 2017). The ambiguous results of the novel object test may be

due to the differences in how the test was conducted across studies. Alternatively, these results could indicate that this test is not ecologically valid for pigs in the way researchers expect it to be. Pigs are naturally curious, generalist omnivores, so novelty may not be something inherently fearful to them.

Overall, the comparisons between variables of the different behavior tests are convoluted, and until the validity of tests are better understood, comparisons across tests may be difficult to interpret. Pigs' behavioral responses are consistent across situations which would be indicative of stable personality types in pigs (Hessing et al., 1993, 1994; Erhard et al., 1999; van Erp-van der Kooij et al., 2002; Janczak et al., 2003; Adock et al., 2015; Horback & Parsons, 2016, 2018; Zebunke et al., 2017), with traits related to exploration (Adcock et al., 2015; Horback & Parsons 2016, 2018), aggressiveness (Hessing et al., 1993; Ruis et al., 2000; Horback & Parsons, 2016, 2018), and reactivity to humans (Giroux et al., 2000; Horback & Parsons, 2016) being the most readily identified. Comparisons of variables across tests can provide additional insight into the personality traits in pigs, but many of the relationships were low to moderate in strength or inconsistent. However, comparisons across studies should be treated with caution due to vast differences in methodologies used to assess and categorize pigs. Researchers need to be more consistent in their experimental designs and analyses, have a better understanding of how experimental design affects the traits being measured, and ask whether the methods being used are ecologically relevant to pigs to better understand how many personality dimensions are present in pig populations.

3.4.2 Investigating relationships between personality types and physiological parameters

The second most commonly studied topic in the pig personality literature is how personality relates to physiological parameters such as overall health, immune response, growth rate, meat quality and stress response. Figure 4 depicts the relationship between behavior tests used to measure personality traits and measures of physiological parameters.

The backtest was used in 17 of the 20 studies in this category, so similarly to many of the studies reviewed above in 3.4.1, researchers investigated the differences between pigs classified into proactive and reactive coping styles. Physiological differences in coping styles were found in 76.4% of the studies,

with only three studies reporting no difference between coping styles and one reporting ambiguous results. For example, when housed in a metabolism chamber, proactive pigs had lower average daily gain and energy metabolizability than reactive pigs, suggesting they were more stressed by the change in environment, supporting the theory that proactive pigs are more rigid in their response to their environment (Geverink et al., 2004a). Reactive pigs housed in barren environments also had different immune responses compared to reactive pigs in enriched environments and proactive pigs in either environment (Bolhuis et al., 2003). Proactive and reactive pigs also differed in their stress response, with proactive pigs displaying a sympathetic response to stress and reactive pigs expressing a parasympathetic response (Hessing et al., 1994a). Proactive and reactive pigs also had different behavioral responses to an apomorphine challenge (Bolhuis et al., 2000), physiological responses to a restraint test (Geverink et al., 2002b), heart rate and vagal tone during resting, feeding, and handling (Krause et al., 2017), immune responses (Schrama et al., 1997), and production parameters such as leanness and carcass grading (van Erp-van der Kooij et al., 2000) though backfat thickness and loin muscle areas were similar (Cassady, 2007). Pigs of different coping styles differed in their average daily gain before but not after weaning, but there were conflicting results on which coping style gained more weight pre-weaning (Cassady, 2007; Camerink et al., 2014). The combination of individuals of each coping style in a pen affected average daily gain, carcass weight, carcass classification, and meat quality. Pigs in pens of equal numbers of proactive and reactive pigs had better productivity. Pens composed mostly of reactive pigs had more stomach wall damage at the post-mortem exam compared with pigs from mixed pens or pens with more proactive individuals (Hessing et al., 1994b). In studies that did not use the backtest to classify pigs by coping style, relationships were found between coping styles (as determined by responses in an open field/novel object test and restraint test) and the density of opioid receptors in the brain (Loijens et al., 2002) and feed intake at various time points (Salder et al., 2016).

There appears to be moderate support for a relationship between personality traits and physiological parameters that suggest using personality as a management tool could have positive benefits for pig management by managing pigs in a more individualistic manner that improves health outcomes

and productivity in targeted ways. There are data to suggest that managing the combination of personality types within a pen could affect productivity and welfare (Hessing et al., 1994b), but the feasibility of identifying personality types in a management setting efficiently is currently a problem because of the time, training, and personnel required to reliably and consistently measure these traits (Watters & Powell, 2011). Additionally, while there do seem to be links between personality traits and physiological parameters that could be considered in the breeding and management of pigs, these relationships are as yet unclear and seem to be highly dependent upon a variety of factors such as housing environment, test procedures, and the age of the pigs when physiological variables are measured. Future research should focus on teasing apart the relationship between these variables and personality traits.

3.4.3 Examining how personality influences the prevalence of other behaviors

Major welfare concerns within the pig industry include behaviors such as tail biting, inappropriate maternal behavior, and stereotypies (D'Eath & Turner, 2009). Exploration of how personality traits relate to these behaviors could have important implications in improving the welfare of pigs by using an animal-based measure of welfare that can help pig managers intervene to prevent problem behaviors (Finkemeier et al., 2018). However, no consistent relationships have been found when personality traits have been compared to maternal behaviors, tail biting, stereotypies, and impulsivity; a trait that could influence the prevalence of the aforementioned behaviors.

When comparing vocalizations to personality type, pigs classified as proactive in the backtest vocalized more while being restrained with a nose sling (Geverink et al., 2002). Additionally, types of vocalizations have been shown to be consistent within individuals across the contexts of a social isolation test and human approach test (Leliveld et al., 2017). If vocalizations are linked to certain personality traits, this could help pig managers identify desirable and undesirable traits to help in making breeding and culling decisions. However, more in depth research would need to be done to get to this point of practicality in on-farm management.

Social aggression among pigs is a major welfare concern in the pig industry especially following placement of pigs into new social groups, so it is unsurprising that a number of studies have investigated the role of personality type on aggression towards conspecifics. Pigs classified as proactive in the backtest are consistently more aggressive after mixing into a new social group. Specifically, proactive pigs are quicker and more likely to initiate aggressive interactions, spend more time engaged in aggressive interactions and spend more time bullying other pigs that do not retaliate (Bolhuis et al., 2005; Melotti et al., 2011). Pens with more pigs classified as proactive also had higher lesion counts, higher body temperatures, and higher concentrations of urinary catecholamines and plasma ACTH after regrouping (Ruis et al., 2002). However, contrary to these results, no difference was found between proactive and reactive pigs in their aggressive behavior in a resident-intruder test (D'Eath et al., 2002) although the social context of this test differs greatly from that of a group mixing scenario in a neutral pen. Low but significant genetic correlations between aggressive behavior at mixing and response to a handling-movement test were found, suggesting that social aggression is a component of a suite of traits that are part of pig personality (D'Eath et al., 2009). Proactive and reactive pigs also differed in their response to social support and social isolation tests with reactive pigs being more alert when isolated than when with a familiar pen mate (Reimert et al., 2014). Reactive pigs also show a higher physiological stress response and more exploratory behavior when isolated than proactive pigs (Ruis et al., 2001). Aggressiveness is a consistent personality trait in pigs, with pigs showing consistent fighting strategies and behavior in one social challenge that are also predictive of behavior in other social challenges (Erhard et al., 1997; D'Eath et al., 2009; Camerlink et al., 2016). Therefore, understanding aggressiveness as a personality trait can have very real implications pig management. Finding practical solutions to identifying and grouping different personality types would have positive impacts on the management and welfare of group-housed pigs.

3.4.4 Exploring the heritability or genetic determination of personality

570 The development and maintenance of personality types within a population is the product of an
571 interaction between genes and environment. The genotype, gene expression, including its epigenetic
572 regulation, and parental effects can all predispose an individual to a certain personality type (Biro &
573 Stamps, 2007; Dochtermann et al., 2015). Although the heritability varies between traits, personality has
574 an estimated average heritability of 0.52 across species with aggressiveness and antipredator behavior
575 appearing to have consistently higher heritability than other traits (Dochtermann et al., 2015). The
576 heritability of personality is within the range of traits that are already being selected for in pig breeding,
577 such as weight (0.18-0.32), loin muscle area (0.34), and backfat (0.58; Wurtz et al., 2017). This means
578 that if pig personality is related to improved production and welfare, personality traits can be used to
579 make management and breeding decisions before pigs are sent to market, if doing so would result in
580 improvements in economic traits that are not currently being realized and costs of measuring behavior can
581 be overcome. A heritability of between 0.10-0.56 has been reported for traits measured in the backtest,
582 human approach test, and handling tests (D'Eath et al., 2009; Köhn et al., 2009; Holl et al., 2010; Rohrer
583 et al., 2013; Scheffler et al., 2014a; Iversen et al., 2017). Low to high genetic correlations have been
584 reported between personality traits measured in different tests and feeding behavior, growth, and
585 aggressiveness (D'Eath et al., 2009; Köhn et al., 2009; Holl et al., 2010; Rohrer et al., 2013; Scheffler et
586 al., 2014a). Candidate genes for coping behavior have been identified using a genome-wide association
587 study (Ponsuksili et al., 2015). The results of the above studies suggest that personality traits are under
588 some degree of genetic control in pigs. However, personality traits are developed through the interaction
589 among genes, environment, and experience. Incorporating personality traits into breeding programs may
590 predispose pigs to exhibit certain personality types, but how genes and the environment may interact to
591 influence the personality types ultimately developed by the pigs is unclear. Further research into this
592 relationship would be worthwhile in addressing concerns in both production and biomedical industries.
593 Understanding breed and species differences is important when studying and managing pigs in
594 commercial production and other captive settings, such as in zoological facilities or in biomedical
595 laboratories. There are differences in personality between breeds of domestic pigs (de Sevilla et al., 2009;

Yoder et al., 2011; Val-Laillet et al., 2013) and personality differences between two species of peccaries have also been found (Nogueira et al., 2015). However, no differences in personality were found between domestic pigs and wild boar crosses (Špinka et al., 2000). There were also no personality differences between naturally bred and cloned pigs (Archer et al., 2003). Pigs selected for positive social breeding values (a beneficial heritable effect on the growth of penmates; Camerlink et al., 2013) were more likely to approach a novel object and human, but there were no other differences in personality based on selection related to social breeding values (Reimert et al., 2013). The results of these studies suggest differences in personality between different groups of pigs may be present which is important to consider in future studies of pig personality or when making management decisions.

3.4.5 Studying the effects of housing environment on personality

Pig housing systems have become a primary welfare concern for consumers, particularly the lack of enrichment, aggression in group-housing systems, and restriction of movement and stimulation in individual gestation stalls. As such, numerous studies have investigated the relationship between housing environment and personality type. The results of these studies suggest that pigs that are reactive in the backtest are more influenced by their housing environment than proactive pigs and that housing environment influenced reactive pigs' immune response, manipulative oral behavior towards penmates and non-food items, ability to complete a cognitive task, play behavior, and incidences of gastric lesions (Bolhuis et al., 2003, 2004, 2005, 2006; Melotti et al., 2011). Pigs classified as proactive in the backtest had won more fights if they were from enriched housing but were overall more aggressive regardless of housing environment (Bolhuis et al., 2005, 2006; Melotti et al., 2011). When relative influence of rearing environment or current environment has been investigated, current housing appears to be more influential. For example, pigs reared in enriched environments and switched to barren environments show less activity, including less play and exploration, even when compared to pigs that remained in barren environments. Pigs switched from enriched to barren environments also showed increased levels of oral manipulative behavior towards pen mates and more gastric lesions at slaughter. These differences in

behavior were particularly apparent in pigs that had been classified as reactive in the backtest (Bolhuis et al., 2006). The results of these studies provide support for an effect of housing environment on the behavior of pigs of different personality types. However, it should be noted that studies from other research groups found no difference between pigs of different backtest classifications or found that proactive pigs also show differences based on housing environment (Geverink et al., 2004; Kanaan et al., 2008; Melotti et al., 2011).

3.4.8 Testing the consistency of behavior tests in identifying personality

Studying animal personality specifically to improve the management and welfare of animals is a relatively new area of research. There have been many questions regarding the appropriateness of different behavior tests in identifying personality types in pigs, particularly how consistent they are, as discussed in section 3.1.3. Responses in the backtest, human approach test, novel object test, and open door test showed low to moderate consistency over time. The studies reviewed here were conducted on pigs of varying ages with different intervals between tests. Amount of time between repeated tests is an important factor to consider, as it has been shown that shorter intervals between repeated tests leads to more consistency between test results than longer intervals (Scheffler et al., 2014b). Reliability and validity of behavior tests used in studying pig personality are crucial areas of research that are needed in order to move forward in understanding the implications of individual pig personalities on their management and welfare.

3.4.9 Considering the role of personality on learning and cognition

Pig cognition has been tested using cognitive bias tests, mazes and Go-No Go tasks (an operant conditioning task where pigs distinguish between two stimuli, one of which is linked to a reinforcer; Lind & Moustgaard, 2005). Housing environment and human handling can influence learning and cognition in pigs. Proactive pigs are more active and bolder towards novel situations, but are less flexible in coping with changing environments, whereas reactive pigs are more receptive to environmental cues, take longer

to explore new environments, and are more flexible (Bolhuis et al., 2004; Jansen et al., 2009). These differences in behavior make reactive pigs generally better at solving cognitive challenges, such as reversal learning in a T-maze task, although housing environment can greatly influence reactive pigs' responses (Bolhuis et al., 2004). Backtest classification was also related to pigs' responses to novel environment and memory tests, with proactive pigs, in general, being more bold, active, and vocal. The interaction between housing and backtest classification was related to pigs' response in the memory test also, with proactive pigs from enriched environments being more active in subsequent memory trials compared with barren housed proactive pigs or reactive pigs. Backtest classification was not related to the number of errors or time to complete the memory test, however (Jansen et al., 2009). Pigs labelled as reactive in a backtest were more hesitant of a novel object if they had been housed in a barren environment, compared with reactive pigs in enriched environments or proactive pigs in either environment, providing evidence that personality type interacts with past experiences to influence cognitive bias (Asher et al., 2016). Personality traits and past experiences also influenced pigs' ability to complete a Go-No Go task, particularly influencing the number of sessions needed to learn the task successfully (Lind & Moustgaard, 2005; Brajon et al., 2016). Thus, there appears to be evidence that personality type interacts with environment and past experiences to influence learning and cognition in pigs, and that some personality types are more likely to be affected by negative experiences than others. These findings could influence study results in a variety of disciplines, and careful consideration should be made regarding housing environment and human-animal interactions to ensure refinement of experimental techniques.

3.4.10 Predicting future behavioral or physiological outcomes based on personality

One goal of researching personality in pigs is to gain the ability to use behavior tests at a young age to identify personality types from which to predict later behavioral and physiological outcomes. This would allow pig caretakers to make informed management and breeding decisions to maximize efficiency of resources and would allow more individualized care that could improve welfare. However, due to the

674 complexity of animal personality, inconsistencies currently present in pig personality research, and the
675 lack of research in this area, applied ethologists are far from this goal. Two studies found that personality
676 traits were related to later growth (discussed below; Giroux et al., 2000; van Erp-van der Kooij et al.,
677 2003) while one found no relationship (Geverink et al., 2002). High social rank and a passive response to
678 stressors were associated with post-weaning growth in early weaned piglets (Giroux et al., 2000), while
679 pigs classified as proactive in a backtest at 10 and 17 days of age had higher daily weight gain in the
680 suckling and fattening periods, respectively (van Erp-van der Kooij et al., 2003). Pigs showing more fear
681 towards human in a human approach test at 8 wk of age had poorer reproductive performance at 1st parity
682 (Janczak et al., 2003b). In a study by Horback and Parsons (2018), activity at 5 wk of age predicted
683 activity at 1st parity and low fear of humans at 3 mon of age. Resistance to being held and cautious
684 behavior at 5 wk of age, and response to humans handling her first litter predicted aggressive/dominant
685 behavior at 1st parity. Response to handling of pre-pubertal gilts observed at 5 weeks of age has been
686 related to behavior at their first parity (Horback & Parsons, 2018). These results could have promising
687 implications for breeding sows if these results are reproducible in future studies. Currently, the predictive
688 power of personality traits is unknown. While a few studies show positive results (Giroux et al., 2000;
689 van Erp-van der Kooij et al., 2003, Horback & Parsons, 2018) these were done on pigs at different stages
690 of production and using different methods, making comparisons across studies difficult.
691
692 **4 Recommendations for future studies**
693 The purpose of this paper was to review studies on pig personality in order to highlight the issues
694 currently present in this area of research and identify the knowledge gaps in most need of addressing. The
695 study of personality in pigs is relatively new. However, studies of pig personality have been steadily
696 increasing in recent years, which means that a framework specific to pigs aimed at outlining correct
697 terminology and methodologies is needed. With a consistent framework in place, results would be more
698 easily compared across studies, bringing us closer to being able to make practical recommendations to pig
699 managers for incorporating pig personality information into their breeding, care and welfare.

Based on this literature review, we have identified four major issues with personality studies in pigs. First, studies investigating pig personalities often have unclear hypotheses regarding what personality traits are being measured by behavior tests. Second, there are inconsistent methodologies across studies in test and statistical methodologies that can influence study results and make comparisons across studies difficult. While some variation in test methodology is expected, the way in which pigs are tested could affect which traits are actually being measured. For example, whether pigs are tested alone or in a group or in a familiar or novel environment. Not enough is known about how these test conditions influence pigs' responses, and therefore tests conducted under varying conditions cannot be said to be measuring the exact same trait as similar tests without further validation. This leads to the third issue seen within the literature, which is the lack of testing and reporting on reliability and validity of behavior tests. In the studies that have assessed reliability, behavior tests used in pigs generally have at least low to moderate repeatability, which is promising for future applications. The relevance of the specific tests to assess personality with respect to pigs' behavioral ecology needs to be further investigated to narrow down the most appropriate tests for measuring desired personality traits. Currently tests measuring aggressiveness and food motivation have found consistent results, suggesting these are appropriate tests for pigs. Lastly, the age of the pigs used in studies of pig personality is a major concern. Personality traits can be influenced by age and experience (Janczak et al., 2003; Forkman et al., 2007) and most of the studies included in this review concluded before the pigs were 6 months of age. Therefore, little is known about how personality changes as pigs age and when personality may become more stable, limiting the scope of the applicability of this research on farm.

Based on these issues present in the literature, we have a number of recommendations for future studies. Future studies on pig personality should move away from the backtest and coping styles hypotheses. The backtest was used in 67.5% of the studies included in this review even though it is unclear what personality trait this test is actually being measured. While it does appear that the backtest is capturing some aspects of personality, the results of backtest studies have been inconsistent suggesting that it is likely not an ecologically valid test of personality in pigs. The framework of ecologically valid

traits and tests proposed by Gosling (2001) and Réale and colleagues (2007) could be used as a starting point moving forward. Validation of tests used to measure pig personality should also be a top priority in future studies. To validate tests, pigs should be tested in multiple test situations, such as individually or in a group and in familiar and novel environments to elucidate how test situations influence pigs' responses. Following an ecologically valid framework and having a better understanding of validity of tests used on pigs will help make studies more consistent, thus improving our ability to make comparisons across studies and provide recommendations to pig managers. It is also recommended that researchers interested in pig personality conduct longitudinal studies on pigs starting at birth and continuing well through maturity. Longitudinal studies would provide insight on which traits remain consistent as pigs age, allowing us to identify traits that could be used to predict future outcomes and can be used to make management decisions.

5 Conclusions

In summary, pigs appear to have personality types that are related to or affected by factors important to their management and welfare including physiology, housing environment, social behavior, and cognition. However, the field of pig personality research currently has issues that prevent the application of this information to making realistic management recommendations. Future studies on pig personality need to be reliable and valid, built on assessment of traits and using tests that are ecologically relevant to pigs and that can be consistently applied across studies.

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Table 1: A list of the 83 peer-reviewed journal articles used in this review. *Study objectives* include: identifying categories of pigs (personality type), physiological parameters (physiology), relationship with other behaviors (behavior), genetic influence (genetics), effects of early life or current housing (housing), consistency of behavior tests (consistency), learning and cognition (cognition), and predicting future outcomes of the pigs (predicting)). Personality assessment methods include: activity/behavior in home pen (HOME), aggression at mixing (AGG), backtest (BT), delay discounting task (DDT), emergence test (ET), extinction test (EXT), food competition test (FC), food motivation test (FM), handling-movement (HM), handling-other (HO), human approach test (HAT), novel object test (NOT), novel rope test (NR), open door test (ODT), open field test (OFT), resident-intruder test (RI), restraint test (RT), social challenge test (SC), social dependence test (SD), social isolation test (SI), and towel test (TT). A description of these tests is provided in Table 2.

Source Citation	Study Objective	Term Used	Sample Size	Breed	Age	Personality Assessment Used	Other Methods Used
Adcock et al., 2015	Personality type	Coping style	20	Yucatan mini pigs	28-36 wk	FC, HAT, NOT, SI	Saliva sampling
Archer et al., 2003	Populations	Temperament	17	Duroc	0-27 wk	BT, HO, TT, HOME	Naturally bred vs. cloned pigs, food preference test
Asher et al., 2016	Cognition	Coping style	36	Large White x Landrace	6-10 wk	SI, NOT	Barren vs. enriched housing, cognitive bias test
Bolhuis et al., 2000	Physiology	Coping style	20	Great Yorkshire x Dutch Landrace or Great Yorkshire x Dutch Landrace	1-18 wk	BT	Apomorphine injection
Bolhuis et al., 2003	Housing, Physiology	Coping style	38	Dutch Landrace x Yorkshire	1-9 wk	BT	Immunization
Bolhuis et al., 2004	Cognition, Housing	Coping style	60	Pietrain x (Large White x (Duroc x British Landrace)) and Pietrain x (Great Yorkshire x Dutch Landrace)	1-8 wk	BT	Barren vs. enriched housing, T-maze
Bolhuis et al., 2005a	Housing	Coping style	60	Dutch Landrace x Yorkshire	1-19 wk	BT, HOME	Barren vs. enriched housing
Bolhuis et al., 2005b	Sociality	Coping style	60	Yorkshire x (Yorkshire x Dutch Landrace)	1-4 wk	BT, AGG	Barren vs. enriched housing

Bolhuis et al., 2006	Housing	Coping style	120	Yorkshire x Landrace	1-10 wk	BT, HOME,	Barren vs. enriched housing, weight gain, feed intake, pathological exam at slaughter
Brajon et al., 2016	Cognition	Temperament	45	(Yorkshire x Landrace) x Duroc	3-10 wk	HAT, NOT, OFT	Chronic gentle, chronic rough, or minimal contact treatments, Go-No Go task
Brown et al., 2009	Personality type, Consistency	Coping style	120	Purebred Landrace, Yorkshire x Landrace, Yorkshire x Duroc	10-24 wk	HAT, FC, NOT, ODT	Lesion scores
Camerlink et al., 2014	Physiology	Coping style	992	German Landrace and Large White	0-4 wk	BT	Teat order, body weight, general health
Camerlink et al., 2018	Genetics	Coping style	480	Topig-20 and Temp	0-23 wk	BT, HOME	High vs. low indirect genetic effects lines
Cassady, 2007	Personality type, Physiology	Coping style	150	Yorkshire x Landrace sows to Duroc boars	0-22 wk	BT, RI	Average daily gain, backfat thickness, loin muscle area, fat-free leanness
D'Eath et al., 2002	Sociality	Temperament	176	(Large White x Landrace) x Large White	0-7 wk	BT, RI	
D'Eath et al., 2009	Personality type, Sociality, Genetics	Temperament	1663	Swedish Yorkshire and Swedish Yorkshire x Swedish Landrace	10-22 wk	AGG, HM, HOME	Genetic analysis
de Sevilla et al., 2009	Populations	Personality	119	Purebred Large White, Purebred Landrace	4-16 wk	BT, HM, NOT, OFT, RT	
Erhard & Mendl, 1999	Personality type	Coping style	29	(Large white x Landrace) x Large white	3 wk	BT, ET	

Erhard et al., 1999	Personality type, Consistency	Coping style	219	(Large white x Landrace) x Large white	2-10 wk	BT, HM, HO	
Forkman et al., 1995	Personality type	Coping style	110	Yorkshire, Swedish Landrace, Hampshire, Duroc	1-9 wk	BT, EXT, FC, NOT, RI, SD	
Friel et al., 2016	Housing	Coping style	72	Large White x Landrace	6-8 wk	NOT, SI	Barren vs. enriched housing, injuries, vocalizations
Geverink et al., 2002a	Predict	Coping style	52	Pietrain x (Large White x (Duroc x British Landrace))	1-29 wk	BT, FC	Oestrous detection, cortisol, heart rate
Geverink et al., 2002b	Physiology, Behavior	Coping style	72	Pietrain x (Large White x (Duroc x British Landrace))	0-14 mo	BT, RT	Cortisol and heart rate response
Geverink et al., 2003	Physiology, Behavior	Coping style	72	Pietrain x (Large White x (Duroc x British Landrace))	0-14 mo	BT	Stereotypic behaviors, cortisol, heart rate, pathological examination
Geverink et al., 2004a	Physiology	Coping style	72	Pietrain x (Large White x (Duroc x British Landrace))	0-13 mo	BT	Weight gain, climatic respiration chambers
Geverink et al., 2004b	Physiology, Housing	Coping style	72	Pietrain x (Large White x (Duroc x British Landrace))	0-14 mo	BT	Individual vs. group housed, immunization
Giroux et al., 2000	Personality type, Predict	Temperament	252	Yorkshire, Yorkshire x Landrace, Duroc	2-4 wk	FC, HAT, OFT	
Goursot et al., 2018	Behavior	Personality	80	German Landrace	5-7 wk	BT, HAT, NOT, ODT	Vocalizations
Hayne & Gonyou, 2003	Personality type	Personality	89	PIC Hybrids	0-18 wk	BT, HM, HAT, HAT/NOT, HOME	Social behavior, teat order, suckling behavior
Hessing et al., 1993	Personality type	Coping style	219	Yorkshire x Danish Landrace	1-15 wk	AGG, BT, SC	

Hessing et al., 1994a	Personality type, Physiology	Coping style	219	Yorkshire x Danish Landrace	1-21 wk	BT, OFT/NOT, SC	ACTH challenge, cortisol and cardiac responses, pathological exam at slaughter
Hessing et al., 1994b	Physiology	Coping style	197	Dutch Landrace x Great Yorkshire	1-25 wk	AGG, BT	Weight gain, post-mortem exam
Holl et al., 2010	Genetics	Temperament	2186	Large White, Duroc, Landrace	22 wk	HM	Weights, backfat thickness, heritability, genetic correlations
Horback & Parsons, 2016	Personality type	Personality	130	PIC 1050	2-4 parity	AGG, FC, HM, HAT, OFT/NOT	Lameness, body condition score, lesions, reproductive success
Horback & Parsons, 2018	Personality type, Predict	Coping style	36	Yorkshire x Landrace	0-18 mo	AGG, ET, HO, HAT	Teat order, response to litter restraint
Ison et al., 2015	Behavior	Temperament	24	Large White x Landrace	20-32 wk	HAT, NOT	Farrowing crate vs. pigSAFE pen postural and behavioral changes
Iversen et al., 2017	Genetics	Coping style	992	Tempo x Topigs-20	2-3 wk	BT	Weight gain, fat depth, loin muscle area, heritability, genetic correlations
Janczak et al., 2003a	Personality type	Coping style	92	Danish Landrace x Yorkshire	3-24 wk	BT, HAT, NOT, RI	Estrous checks
Janczak et al., 2003b	Behavior	Personality	89	Danish Landrace x Yorkshire	8 wk to 1st parity	HAT, NOT	Maternal behavior, reproductive success
Jansen et al., 2009	Cognition	Coping style	24	Great Yorkshire x (Great Yorkshire x Dutch Landrace)	1-12 wk	BT	Barren vs. enriched housing, exploration maze, memory test, general activity, posture, and location in maze

Jensen et al., 1995	Personality type	Coping style	42	Yorkshire/Landrace x Hampshire	0-5 wk	OFT/NOT, RI	Post-partum behavior, post-suckling behavior
Kanaan et al., 2008	Housing	Coping style	90	Yorkshire x Landrace	0-2 wk	BT, SC, SI	Socialized vs. unsocialized piglets, weight gain, injuries, suckling behavior
Köhn et al., 2009	Genetics	Temperament	10,033	Goettingen minipigs	8-24 wk	HM, HO	Genetic analysis
Krause et al., 2017	Physiology	Coping style	14	German Landrace	11-13 wk	BT, HAT	Heart rate, blood pressure, body temperature, autonomic responses to feeding and HAT
Lawrence et al., 1991	Personality type	Temperament	62	Landrace x Large White	7-8 mo	FC, HM, HAT, NOT, ODT, RT	
Leliveld et al., 2017	Behavior	Personality/ Coping style	120	German Landrace	4-5 wk	BT, HAT, NOT, ODT, OFT, SI	Vocalizations, heart rate
Lind & Moustgaard, 2005	Cognition	Temperament	12	Göettingen minipigs	24-36 wk	NOT	Go-No Go Task
Loijens et al., 2002	Physiology	Coping style	18	Large White x British Landrace	7-8 mo	OFT/NOT, RT	Density of opioid receptors at slaughter
Magnani et al., 2012	Personality type	Coping style	132	Landrace x Large White	1-6 wk	BT, ET, NOT	
Melotti et al., 2011	Social, housing	Coping style	128	Tempo x Topigs-30	2 wk	BT, HOME, AGG	Barren vs. enriched housing, lesion scores
Melotti et al., 2013	Physiology, Behavior	Coping style	16	Duroc x Large White x Landrace	1-15 wk	BT, DDT, AGG	Urinary serotonin and dopamine levels
Nogueira et al., 2015	Populations	Temperament	36	White-lipped and Collared Peccaries	3-8 yr	HM	
Oster et al., 2015	Physiology	Coping style	3555 for backtest, 252 for	German Landrace	0-8 wk	BT	Immunization

			immune challenge, 48 for gene expression				
Ponsuksili et al., 2015	Genetics	Coping style	294	German Landrace	0-4 wk	BT	Genetic analysis
Reimert et al., 2013	Populations	Personality	543-1009	Topigs-20 and Tempo	1-4 wk	BT, HAT, NOT, OFT	
Reimert et al, 2014a	Sociality	Coping style	72	Tempo x Camborough	1-11 wk	BT, SI/SD	Cortisol, heart rate
Reimert et al., 2014b	Genetics	Coping style	480	Topigs-20, Tempo	2-23 wk	BT, HAT, NR, OFT/NOT	Positive and negative social breeding value lines, barren vs. enriched housing, saliva, cortisol
Reimert et al., 2014c	Physiology	Coping style	480	Topigs-20 and Tempo	4-23 wk	BT	Positive and negative social indirect breeding values, blood parameters
Rohrer et al., 2013	Genetics	Coping style	2007	Landrace x Duroc x Yorkshire	0-22 wk	BT, HM	Feeding behavior, weight, backfat thickness, genetic analysis
Ruis et al., 2000	Personality type, Consistency	Coping style	128	Great Yorkshire x (Great Yorkshire x Dutch Landrace)	0-25 wk	BT, FC, ODT/HAT	Teat order, ACTH challenge
Ruis et al., 2001	Sociality	Coping style	281	Great Yorkshire x (Great Yorkshire x Dutch Landrace)	0-10 wk	BT	Housed in isolation, blood, saliva, and urine samples, body temperature, weight, feed intake, postmortem exam
Ruis et al., 2002	Sociality	Coping style	96	Great Yorkshire x (Great Yorkshire x Dutch Landrace)	0-10 wk	BT, AGG, ET/NOT	Lesion scores, blood, saliva, and urine samples, body temperature, heart

							rate, growth rate, feed intake
Salder et al., 2016	Physiology	Temperament	192	Yorkshire	12-28 wk	HM	Low- and high-residual feed intake lines
Scheffler et al., 2014a	Consistency, Genetics	Coping style	1382 piglets, 272 gilts	German Landrace, Large White	1-22 wk	BT, HAT	Genetic analysis
Scheffler et al., 2014b	Personality type, Consistency	Coping style	1383 piglets, 272 gilts	German Landrace and Large White	2-22 wk	BT, HAT	
Schouten & Wiepkema, 1991	Behavior	Coping style	22	Dutch Landrace x Yorkshire	Primiparous sows	RT	Stereotypic behavior
Schrama et al., 1997	Physiology	Coping style	24	Dutch Landrace, Finnish Landrace, Great Yorkshire	0-10 wk	BT	High and low hemoglobin groups, climate respiration chambers, immunization, growth rate, food consumption, blood samples
Spake et al., 2012	Personality type	Coping style	575	Not specified	1-6 wk	BT, NOT, RI	Heart rate, weight gain
Spinka et al., 2000	Populations	Temperament	14	Yorkshire x Dutch Landrace, 7 sired by Yorkshires and 7 by wild boars	20-24 mo	HAT	Maternal behaviors, behavioral observations, cortisol levels
Spoolder et al., 1996	Personality type	Behavioral type	205	PIC Camborough	12-24 wk	FC, FM, HOME, NOT	
Thodberg et al., 1999	Personality type	Temperament	56	Landrace x Yorkshire	16 wk	HOME, FC, HAT, OFT/NOT, RI	
Thodberg et al., 2002	Behavior	Temperament	40	Danish Landrace x Yorkshire	1st and 2nd parity sows	HAT, OFT/NOT	Maternal behavior

Ursinus et al., 2014	Behavior	Coping style	480	Not specified	0-23 wk	BT, NOT, OFT	Tail biting behavior, tail damage, blood serotonin, cortisol
Val-Laillet et al., 2013	Populations	Temperament	63	Pitman-Moore and Vietnamese minipigs	4-7 wk	ET/OFT/HAT	T-maze, Social reunion/separation Y maze
van Erp-van der Kooij et al., 2000	Physiology, Consistency, Populations	Coping style	1389	Dutch Landrace x Great Yorkshire	0 wk to slaughter	BT	Weight gain, leanness, carcass quality, response to piglet removal
van Erp-van der Kooij et al., 2001	Consistency	Coping style	184	Dutch Landrace x Yorkshire	0-2 wk	BT	
van Erp-van der Kooij et al., 2002	Personality type, Consistency	Coping style	315	Dutch Landrace x Yorkshire	0-12 wk	BT, HAT, NOT, ODT	
van Erp-van der Kooij et al., 2003a	Predict	Coping style	812	Dutch Landrace, Great Yorkshire	0-9 wk	BT	Weight gain, leanness
van Erp-van der Kooij et al., 2003b	Physiology	Coping style	882	Dutch Landrace x Great Yorkshire	0-9 wk	BT	Cortisol levels
Vetter et al., 2016	Physiology	Personality	57	Wild boar	6-34 mo	AGG, NOT	Reproductive success
Yoder et al., 2011	Populations	Temperament	4774	Chester White, Duroc, Landrace, Yorkshire	26 wk	HM	Body weight, backfat thickness, loin muscle area
Zebunke et al., 2015	Consistency	Coping style	3555	German Landrace	0-4 wk	BT	
Zebunke et al., 2017	Personality type	Coping style	120	German Landrace	0-8 wk	BT, AGG, HAT, NOT, ODT, OFT/NOT	

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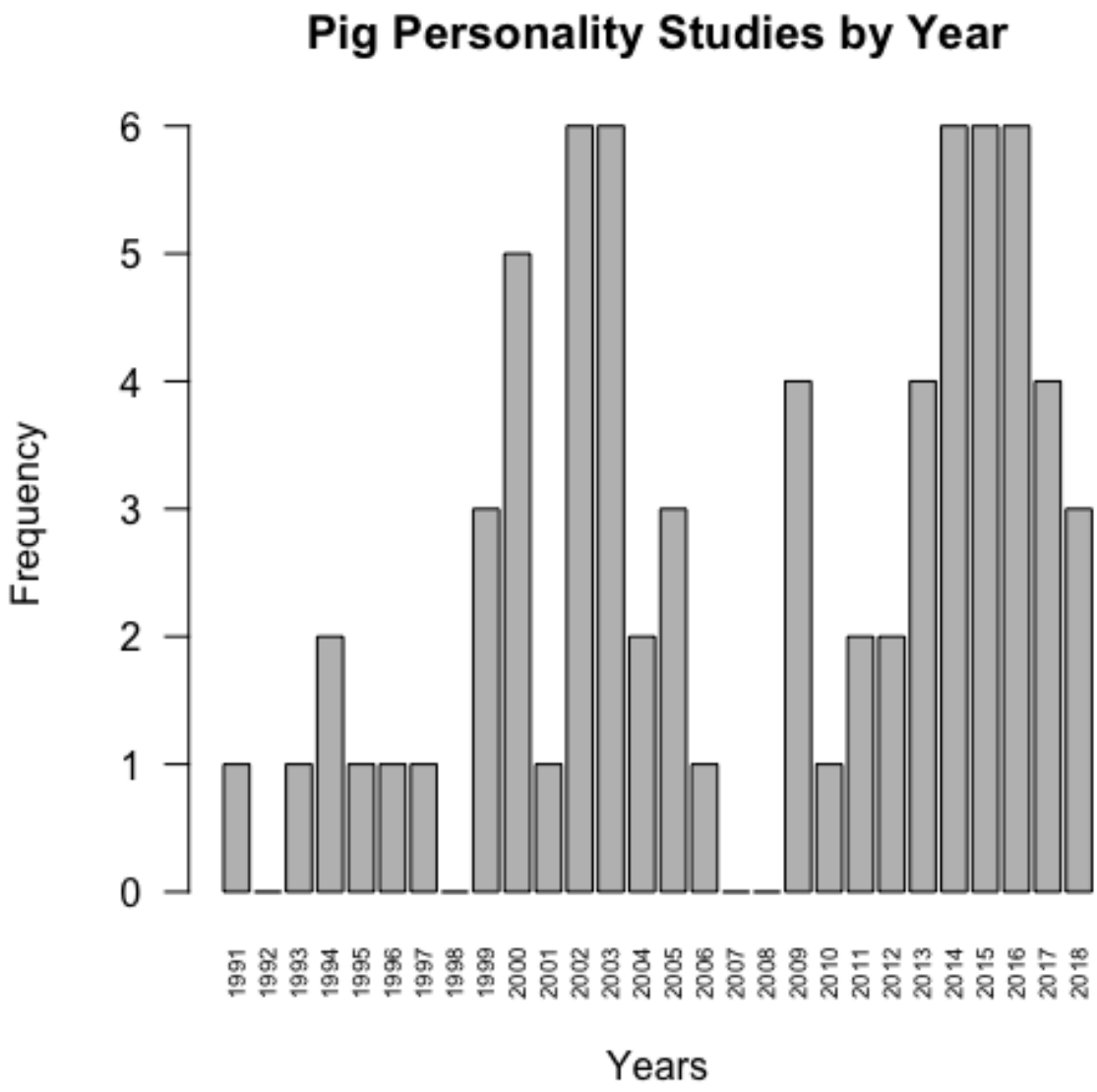

Figure 1: Histogram of number of articles published related to pig personality by year.

Table 2: Behavior tests used to assess personality in pigs, including the personality traits or dimensions related to in the literature, and a description of how the test is generally conducted.

Test	Personality Trait(s)	Description
Backtest	Coping style, behavioral differences, stress-coping behavior, behavioral strategies, fear, response to restraint, resistance, personality, response to stressor,	Piglet is held on its back and the amount of struggling is recorded.
Delay discounting task	Impulsivity	Pig can press a lever to get an immediate small reward or a lever to get a delayed larger reward.
Emergence test	Timidity, activity and exploration, individual reaction patterns, behavioral reactivity	Piglet is placed in an unfamiliar box with an opening to an unfamiliar arena. Latency to leave the box is recorded.
Extinction test	Persistency	Pigs are trained to expect a food reward in a trough and then the food reward is removed. The duration of trough exploration is recorded.
Food competition test	Social status or hierarchy, aggressiveness	A group of pigs is fed simultaneously or using an ESF feeder. Aggression, success at obtaining food, or order of feeding is recorded.
Food motivation test	Food motivation	Pigs are fasted for a certain amount of time. When the pigs are fed next, their behavior is recorded.
Handling test – movement	Response to handling, ease of movement or handling, reactivity to humans, fear, agitation, coping style, temperament	Pigs are moved down a corridor or through a scale. Ease or speed of pig movement is recorded.
Handling test – other	Challenge, fear, coping style, reactivity to humans	Pig is handled for various tasks and its response is recorded. Tasks can include for injection, being caught and held in a handlers arms, being placed on a table or scale, etc.
Human approach test	Exploration, reactivity to humans, fear and exploration towards humans, boldness, activity, fearfulness, response to handling, emotional reactivity, coping style	Pigs' response to a human is assessed. Human may be familiar or unfamiliar.
Novel object test	Coping style, fear and exploration towards novelty, boldness, activity, emotional reactivity, individual reaction patterns, response to novelty, fearfulness, anxiety	An unfamiliar item is presented to the pig and its reaction and interaction with the object is recorded.
Novel rope test	Fearfulness	Ropes are placed in the pigs' home pen. Latency to touch ropes and interaction with ropes is recorded.

Open door test	Motivation and fear leaving pen, boldness, exploration, activity, response to handling, emotional reactivity, coping style	The door of the pigs' pen is opened. The latency to leave the pen and the individual order of pigs leaving is recorded.
Open field test	Exploration, emotional reactivity, fearfulness, anxiety, locomotion activity, response to stress	Pig is brought to an experimental pen and its behavior is observed.
Resident-Intruder test	Aggressiveness	An unfamiliar pig is introduced into the pen of a resident pig. The latency to and amount of aggression between the two pigs is recorded.
Restraint test	Response to handling, response to stressor, coping style	Pig is restrained with a nose sling, with a pig board, or tether and the response is recorded.
Social challenge test	Aggressiveness, coping style	Unfamiliar pigs are introduced in a neutral space and their interactions are recorded. Pigs may be introduced with 1-2 other familiar pigs. For example, three pigs from one litter vs. three pigs from another litter.
Social dependence test	Social dependence	Pig is isolated with familiar pen mates nearby. Its response is recorded.
Social isolation test	Coping style, response to stressor, emotional reactivity	Pig is isolated without contact with other pigs and its response is recorded.
Towel test	Not specified	A towel is placed on the pig's head and latency to remove the towel was recorded.

Table 3: Repeatability for behavior tests used in personality studies, reported as correlation coefficients. Personality assessment methods include: backtest (BT), emergence test (ET), food competition test (FC), handling-movement (HM), human approach test (HAT), novel object test (NOT), open door test (ODT), open field test (OFT), resident-intruder test (RI), and social isolation test (SI).

Source	Behavior Test	Variable	Repeatability	Repetitions	Age of Animals
Adock et al., 2015	FC	Social rank	0.77-0.92	2	28-36 wk
Brown et al. 2009	HAT	Latency to first contact	0.21-0.39	3	23 wk
	NOT	Latency to first contact	-0.05-0.32	3	23 wk
	ODT	Latency to exit pen	0.19-0.38	3	23 wk
Cassady, 2007	BT	Time spent struggling	0.38	2	6-17 d
	RI	Latency to attack	0.18	2	33-44 d
D'Eath et al., 2002	BT	Frequency of struggling Duration of squealing	0.33 0.39	2	3-9 d
	RI	Attack latency	0.42-0.48	2	16-19 d
Erhard & Mendl, 1999	BT	Duration of tonic immobility	0.48-0.68	4	3 wk
	ET	Latency to leave	0.52-0.66	4	3 wk
Friel et al., 2016	NOT	Acoustic signaling Duration standing Duration exploring Latency to contact Duration investigating Line cross frequency	0.48 0.36 0.46 0.29 0.02 -0.11	2	6-8 wk
	SI	Acoustic signaling Duration standing Duration exploring	0.58 0.29 0.48	2	6-8 wk
Horback & Parsons, 2016	OFT/NOT	Number of lines crossed Duration exploring Duration lying Latency to contact Duration contact	0.50 0.10 -0.10 0.20 0.20	2	2-4 parity
	HAT	Response to human	0.50	2	2-4 parity
	HM	Ease of handling	0.40	2	2-4 parity
Janczak et al., 2003b	NOT	Duration object investigation Frequency object investigation Latency to object investigation Duration standing	0.53 0.44 0.28 0.30	2	8-24 wk

		Duration room investigation Duration walking	0.05 0.10		
	HAT	Duration human investigation Frequency human investigation Latency to human investigation Duration standing Duration room investigation Duration walking	0.33 0.29 0.28 0.28 -0.19 0.02	2	8-24 wk
	RI	Attack latency Duration standing Duration walking	0.34 0.28 0.07	2	8-24 wk
Ruis et al., 2000	BT	Number of escape attempts Duration of escape behavior Number of vocalizations	0.17 0.21 0.23	2	2-31 d
	ODT/HAT	Latency to leave home pen Locomotion in corridor Latency to human contact	-0.06 0.21 0.01	2	10-24 wk
	FC	Aggression	0.61	2	10-24 wk
Scheffler et al., 2014b	BT	Number of escape attempts Duration of escape attempts Latency to escape attempts	0.31 0.33 0.43	2	12 day-22 wk
	HAT	Latency to contact human	0.20-0.52	7	2-22 wk
Spake et al., 2012	BT	Time struggling Struggle attempts	0.34 0.13	2	6-13 d
	NOT	Latency to explore Time exploring Contact latency	0.36 0.20 0.09	2	5-6 wk
	RI	Time from contact to attack Attack latency	0.18 0.11	2	5-6 wk
van Erp-van der Kooij et al., 2000	BT	Number of escape attempts	0.39-0.47	3	3-17 d
van Erp-van der Kooij et al., 2001	BT	Number of escape attempts	0.30-0.40	3	3-17 d
Vetter et al., 2016	NOT	Timing of first contact Total duration of investigating	0.17 0.17	9	7 mon
Zebunke et al., 2015	BT	Latency of struggling Duration of struggling Frequency of struggling	0.25 0.39 0.27	4	5-26 d

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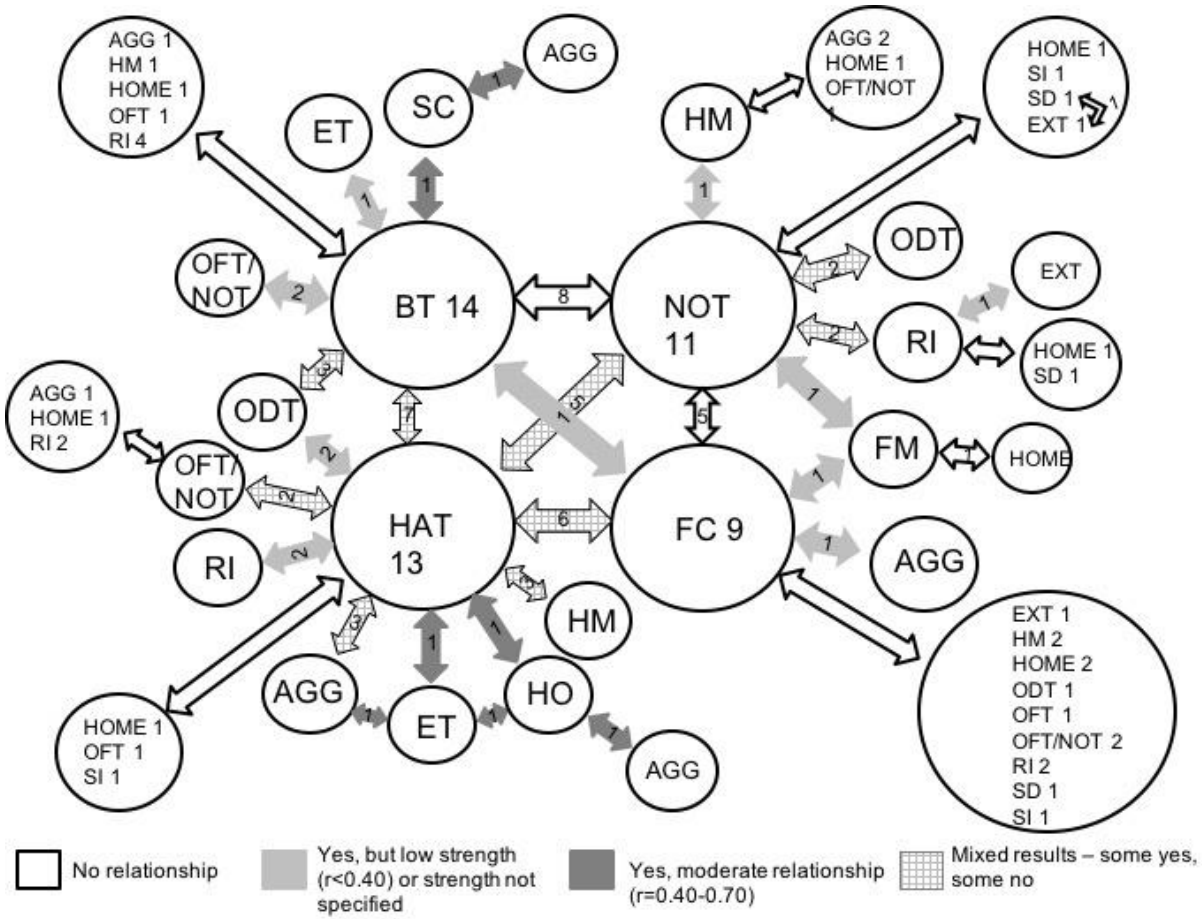

Figure 2: Flow chart of pairwise comparisons between different behavior tests used to identify categories of pigs. A total of 23 studies investigated this topic. The tests in the four center circles were the most used, and the numbers represent the number of times those tests were used in those studies. The numbers next to the arrows represent the number of times those tests were compared. The color of the arrow represents the strength of the relationship between those tests. Behavior tests include: activity/behavior in home pen (HOME), aggression at mixing (AGG), backtest (BT), emergence test (ET), extinction test (EXT), food competition test (FC), food motivation test (FM), handling-movement (HM), handling-other (HO), human approach test (HAT), novel object test (NOT), open door test (ODT), open field test (OFT), resident-intruder test (RI), social challenge test (SC), social dependence test (SD), and social isolation test (SI).

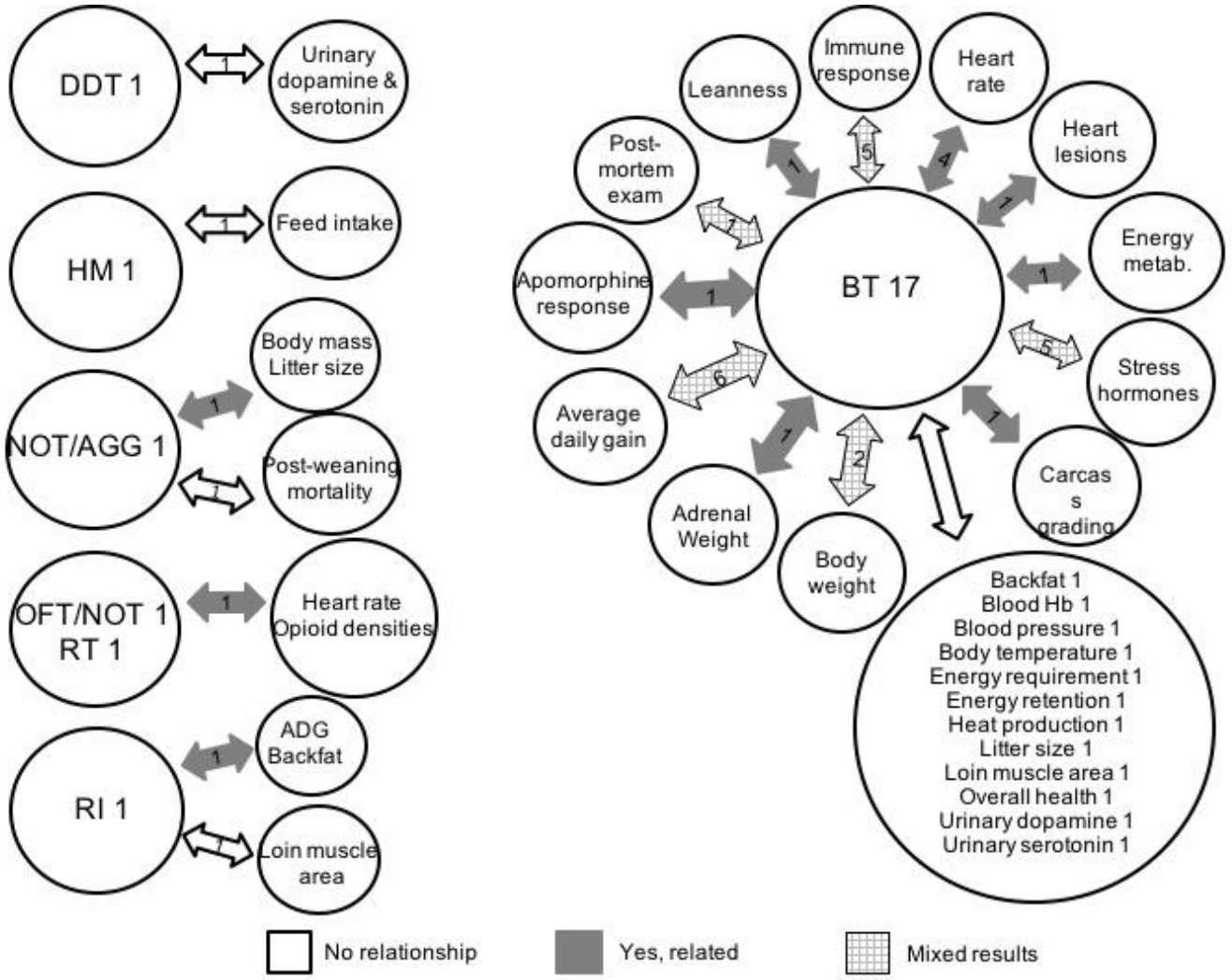

Figure 3: Flow chart of pairwise comparisons between behavior tests and physiological parameters. A total of 20 studies compared personality traits and physiological traits. The numbers next to the arrows represent the number of times those tests were compared. The color of the arrow represents the strength of the relationship between those tests. Behavior tests include: aggression at mixing (AGG), backtest (BT), delay discount task (DDT), handling-movement (HM), novel object test (NOT), open field test (OFT), resident-intruder test (RI), and restraint test (RT).

Highlights

- A total of 83 articles studying the relationships between pig personality, management and welfare were reviewed
- A lack of consistency in terminology and methodology makes comparisons difficult
- Studies have found links between personality, behavioral, and physiological traits
- A framework is needed to incorporate pig personality into management and welfare